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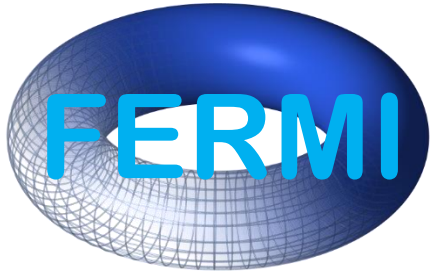
CHANGING WHAT'S POSSIBLE



FUSION ENERGY REACTOR MODELS INTEGRATOR

GAMOW Kickoff Meeting
January 21–22, 2021

PI: Vittorio Badalassi, Distinguished R&D Staff Member, ORNL
Co-PIs: D. Kropaczek, C. Kessel (ORNL), S. Smolentsev (UCLA/HyPerComp Inc.),
P. Huang (HyPerComp Inc.), J. Solberg (LLNL), D. Whyte (MIT/CFS)

U.S. DEPARTMENT OF ENERGY

Team members and roles

PI: V. Badalassi PhD CEng

Responsible for overall program coordination and execution, with full authority for management of the budget, the R&D program, and operations

Co-PI: S. Smolentsev PhD

MHD turbulence models implementation

Validation of HIMAG+PRECICE

LIB preliminary design & validation

Co-PI: P. Huang PhD

HIMAG coupling with PRECICE

Development and Validation of the FERMI software suite

Co-PI: J. Solberg PhD

DIABLO coupling with PRECICE

Development and Validation of the FERMI software suite

Co-PI: C. Kessel PhD

Project advisor

LIB design advisor

Co-PI: D. Kropaczek PhD

Project advisor

Code coupling validation

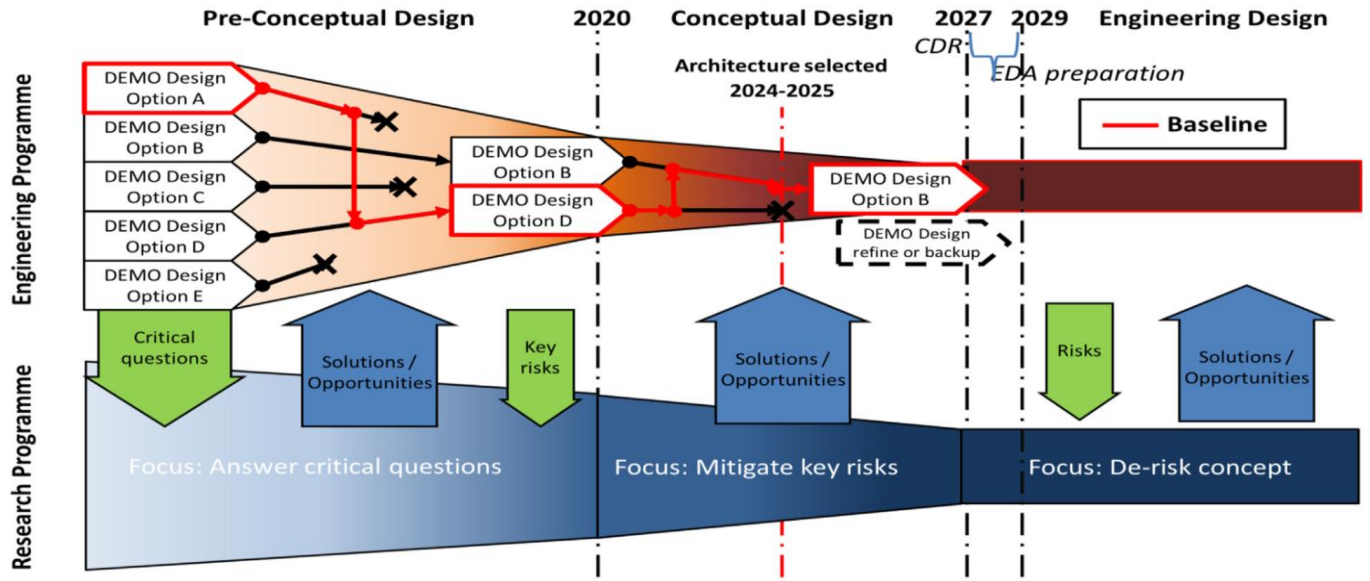
Co-PI: Prof. D. Whyte

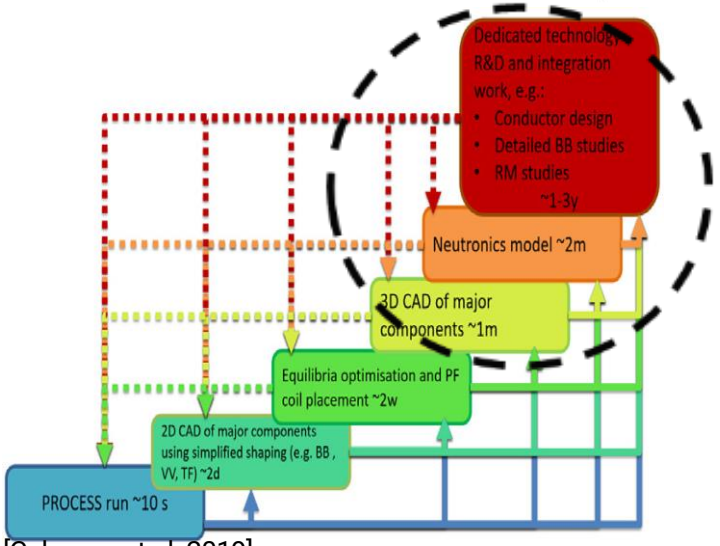
Project advisor

ARC (LIB) inventor & chief designer

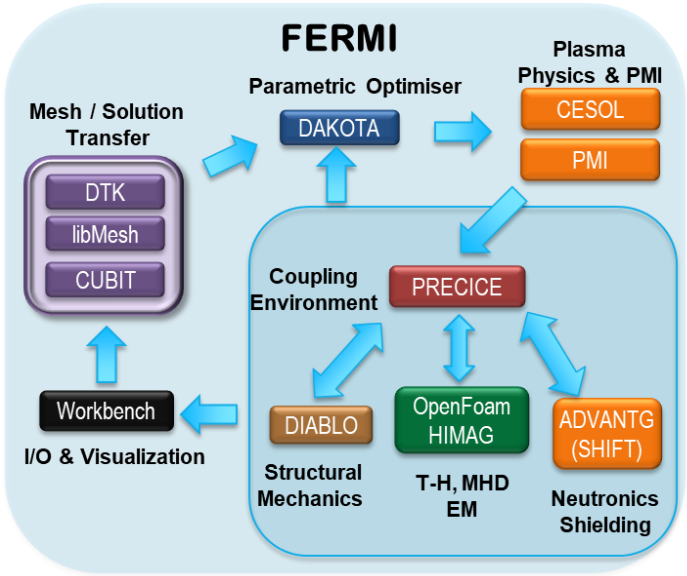
MIT/CFS collaboration with the FERMI team

High-level motivation, innovation, and goals of the project





[Coleman et al. 2019]



Technology Summary

- *Development of a fusion virtual MS blanket*
- *Integrated Multiphysics Environment*
- *Focus on the Liquid Immersion Blanket (LIB)*
- *Validation on available data and results*

Technology Impact

- Speeds up the overall design development by 30 times
- Exceptional fidelity of the engineering calculations
- Enables the development of a commercial fusion reactor

Proposed Targets

Metric	State of the Art	Proposed
Coupled Multiphysics First Wall and Blanket Simulation	*No existing capability*	*FERMI integrated simulation environment*
LIB-FliBe cooled/breed FW & Blanket Proof of Concept	*TRL = 3*	*TRL = 6*
Conceptual Design time	*9 Years*	*3 months*
Design team number and design iterations	*20 engineers and 3 iterations*	*3 engineers and 6 iterations*

CHANGING WHAT'S POSSIBLE

Major tasks, milestones, risks, and desired project outcomes

- Milestones
  - New MHD turbulence models implementation (Q2-2021)
  - Virtual Molten Salt (LIB) Blanket (Q2-2022)
  - Preliminary LIB Concept Design (Q2-2022)
  - LIB design optimized & validated using FERMI (Q3-2023)
  - Documentation, software release, stakeholder workshop (Q4-2023)
- Outcomes
  - Virtual MS blanket 3D simulator
  - Validated & proven LIB-ARC blanket design
  - Reusable software for DCLL and other blankets of tokamak reactors
  - First step towards a FULL fusion virtual reactor

Major Technical Risks
Lack of availability or access to sufficient reliable experimental data for model calibration and validation
Unforeseen software challenges integrating existing capabilities
Numerical challenges related to the coupling of multi-physics
Extreme high dimensionality and nonlinearity of the fully coupled codes posing difficulties for scalable, efficient error estimation, data assimilation, sensitivity analysis, uncertainty quantification, and optimization
Geometrical complexity requiring complex meshing, large problem sizes which reduce turn-around time, leading to modeling errors and/or low-quality meshes creating numerical difficulties

T2M and aspirational follow-on plans

Reactor	Technical & Cost Metric	Present state of the art	Commercial or Development Targets	Achieved by FERMI	Cost Saving
ARC	Technical metric #1	RANS turbulence models (no MHD)	MHD RANS turbulent models built in HIMAG	New RANS MHD put in HIMAG	N/A
	Technical metric #2	Pre conceptual MS Blanket Design -TRL=3	Design built and proven in a lab - TRL=7	Design proven with FERMI - TRL=6	N/A
CPP ARC	Technical metric #3	Design using single codes with partial physics simulation	Full Multiphysics integrated simulations	Coupling of validated codes for blanket simulation	N/A
	Cost metric #1	9 years of design time for baseline blankets	Few months	3 months for a full design - TRL=6	25Mn$
	Cost metric #2	Blanket design needs a team of 20 eng ineers	Less than 5	3 engineers for the design -TRL=6	2.6Mn$/year
	Cost metric #3	2-3 design iterations for optimization	More than 5	6 iterations in the 3 months for design	N/A

- Test & deployment plans/aspirations
  - Enabler of the Affordable, Robust, Compact (ARC) fusion reactor
  - Fits into the CFS path to testing on fusion-scale experiment (SPARC & ARC)
  - Potential Collaborations after the FERMI project:
    - Commonwealth Fusion Systems (ongoing)
    - General Fusion
    - General Atomics
    - Startups
  - Free license to DOE Labs and US companies – export controlled